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## SOME VARIABILITIES AND CORRELATIONS IN LEARNING

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This paper reports an investigation of the following problems: To what extent are the first performance and other early performances measures of succeeding performances? Does practice make an individual's performance more consistent? Does practice make individuals of a group more like one another in their performance? What is the relation of card-sorting to intelligence? What is the relation of gain in card-sorting to intelligence?

Twenty-seven normal school students sorted cards for 25 seconds, 20 successive times during a period of 50 minutes. This was repeated by the same subjects after ten days, then one day later and finally after an interval of three and a half months. Fourteen other subjects fitted 36 cubes, each of whose faces had a separate color, into a box, for 23 successive school days. Of these 14 subjects, 7 knew the time record after each performance, whereas the other 7 at no time during the experiment knew any of their time records.<sup>1</sup> Sixteen of the card-sorting subjects, who had worked together in the same group in all classes for a term, ranked one another in general intelligence.

*To what extent is the early performance the measure of succeeding performances?*

On the basis of the median of each successive five performances in card-sorting the one class of 16 subjects, the other of 10, were ranked.<sup>2</sup>

Correlations between the early ranks and the succeeding ranks, and between the final ranks and others, were then determined. Similar data were derived for the colored cube test. Table I gives these correlations. Considering the two groups for card sorting (A) there is practically no difference between those with the first five and those with the last five. For the color-cube test there is no difference worth mentioning

<sup>1</sup> Hazel Coburn, Helen Collins and Garry C. Myers. Some Studies in Learning. To appear shortly in *School and Society*.

<sup>2</sup> To simplify computation only ten (chosen alphabetically) of this class of 11 were considered.

except in the not-knowing group, where the advantage is decidedly in favor of the correlation with the first five, i. e., in this case the ranking for the average of the first five performances are more like all the succeeding rankings than is the ranking for the average of the last three like all the other rankings. The "not-knowing" group toward the end had less incentive to do their best than the "knowing" group.

Similar data are shown below table (C) from 14 girls, who, learning to use the typewriter, practiced on the same sentence for 3 minutes per day for 25 successive school days. Seven of them emphasized accuracy; the other seven speed. Those who emphasized accuracy tended more to keep the same relative rank throughout than those who emphasized speed. Apparently, then, the learner's knowledge of his rate of speed and his aim to be rapid even at the sacrifice of accuracy tend to increase shifting of relative ranking of individuals within a group.

TABLE I.  
C. TYPEWRITING

	With First		With First Five		With Last Five	
	Accuracy	Speed	Accuracy	Speed	Accuracy	Speed
First five...	.82	.93	1.00	1.00	.18	— .04
Second five..	.57	.31	.89	.43	.86	.25
Third five..	.29	.13	.68	.30	.93	.43
Fourth five..	.13	— .04	.47	.00	.84	.70
Fifth five...	.18	— .04	.64	— .11	1.00	1.00

In card sorting, the correlations with the second five, however, which is about the same as with the seventh five, gives far better results. The initial single performance does not measure very closely the succeeding ten performances. For example, for the 16-group it correlates with the second single performance .71; 3rd, .55; 5th, .60; 10th, .65; and the fifth with the 10th, .76. The correlation of the initial trial with the median of the first is  $+.73$  and for group 10 it is  $+.83$ .

The 10-group have considerably higher correlations, i. e., the relative ranking at any one point on the whole, more closely agrees with all other rankings than for the 16-group. This is significant from the fact that the larger class is a highly selected one, being made up of the best of a class of over 100 whereas the other class is one of the regular sections of the same class.

TABLE I.  
CORRELATIONS  
BETWEEN DIFFERENT STAGES OF PERFORMANCES  
A. Card Sorting (26 subjects)

Successive Five Trials	Class of 16			Class of 10		
	With First Five	With Second Five	With Seventh Five	With First Five	With Last Five	With Last Five
1.....	1.00	.75	.53	1.00	.53	.53
2.....	.75	1.00	.72	.94	.80	.80
3.....	.63	.90	.64	.81	.86	.86
4.....	.65	.89	.72	.95	.83	.83
5.....	.31	.65	.84	.94	.80	.80
(10 days interval)						
6.....	.38	.76	.85	.90	.78	.78
7.....	.53	.72	1.00	.92	.67	.67
8.....	.29	.61	.84	.76	.77	.77
9.....	.35	.60	.70	.75	.80	.80
(1 day interval)						
10.....	.32	.65	.87	.86	.86	.86
11.....	.32	.71	.85	.66	.80	.80
12.....	.51	.71	.82	.67	.83	.83
(3½ months interval)						
13.....	.31	.42	.41	.54	.56	.56
14.....	.24	.49	.35	.53	1.00	1.00
Average.....	.47	.70	.72	.79	.78	.78

	Class of 16	Class of 10
4th with 5th trial.....	.71	.89
8th with 9th trial.....	.86	.70
12th with 13th trial.....	.39	.60
1st with 1st five trials.....	.73	.83

TABLE I.

B. Colored Cubes				
	Subjects not knowing rate	Subjects knowing rate	Subjects not knowing rate	Subjects knowing rate
	First five with		Last five with	
Second five.....	.71	.98	.86	.13
Third five.....	.79	.37	.86	— .03
Fourth five.....	.84	.40	.89	.45
Last three.....	.86	.13	.82	.28

On the other hand the discrepancy seems to be explained largely by the fact that X of group 16, who ranked lowest in her first five, reached the highest maximum record for the class on her 60th trial and fell to the 11th place in her last five trials. Her relative positions by fives throughout are 16, 13, 11, 11, 4, 2.5, 4, 3, 3, 3.5, 2.5, 4, 13, 11.5. No other such record was found in this or the other group.

Apparently, for card-sorting at least, the first five trials are about as representative of all the others as are the last five.

Putting the problem in another way. *To what extent do the performers maintain their relative rankings throughout?*

Table below shows that of class 10 those who were in the lower half of the group at the start remained there as a rule. In only 8 of the 14 series of 5 were there exceptions and there only one case per series. The shiftings were limited to 4 persons. The letters in the second row indicate individuals of the lower half who shifted to the upper half on the respective trials.

Rank (in series of five)...	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Shifts from 2nd to 1st half	-	B	K	-	-	-	C	C	K	-	K	K	O	-

Excepting the one "abnormal" case, of class 16, similar consistency in ranking obtained throughout the periods of performance.

By reference to the table of correlations between the rankings at various points in the curve of practice, one sees there strong evidence that, as a rule, the individuals tended to maintain the same relative position throughout. This is a bit more evidence of original nature.

Thorndike found a Pearson coefficient of .48 between first and last performance in addition. Those who start out best come out best after a moderate amount of practice. His 10 individuals who led at the beginning gave at the close of the hour 23.5 examples per hour; next 10 gave 20.0; remaining 8 (lowest) only 11.1.<sup>3</sup>

In a similar experiment in addition by 4th grade children Thorndike found that those who start out best come out best.

Wells by addition and cancellation tests found on the whole the same relative position before and after practice.<sup>4</sup>

Hollingworth (*Vocational Psychology*, Ch. XI) put each of 13 individuals through 205 repetitions of seven different mental tests, 5 trials, at 2½ hour intervals, made daily. Corre-

<sup>3</sup> Variability between Individuals. *Amer. Jour. Psychol.*, 1908, 19: 374.

<sup>4</sup> *Amer. Jour. Psychol.*, 1912, 23: 75.

lating the ranking of the subjects in trials 171-175 with that of the first trial, with the median of trials 1 to 5, of 20 to 25, of trials 46 to 50, of trials 76 to 80, and of trials 126 to 130, he got for the 13 tests, average correlations of .41, .61, .73, .77, .85, .92, respectively. Hollingworth concludes: "It is at once evident that the preliminary trial is by no means always a measure of the final relative capacities of the individuals tested. . . . As the trials proceed, then, the relative positions of the thirteen individuals became more and more definitely fixed, but in the beginning the indication is obscure."

Forthwith Hollingworth calls into question the reliability of determining an individual's capacity on the basis of one or a dozen trials at tests, and he states that in case numerous trials are not expedient, only those tests should be used whose results in initial performance correlate very highly with the performance after a very large number of trials. For real diagnostic value he has the conviction that "we shall find it necessary to determine the individual's limit of practice in the various tests before we shall secure diagnostic results which will be verified by the individual's subsequent achievement in daily life."

Certainly the desirability of determining the individual's maximum capacity in any test is undoubted. Hollingworth's assumption, however, that the 171-175 trials represent the highest capacity of the subjects may be questioned. His results merely measured what the individuals *did* on those trials. The learning curve in card-sorting reported elsewhere clearly shows that when on the twentieth trial of the two days the writer told the subjects that it was the last and urged them to do their very best they made a decided spurt considerably above their highest record. This the writer has invariably found for several terms with the card-sorting test used as a regular class experiment. Several performers said they could scarcely drive themselves to the task on the third day's performance because of the monotony of the task. Suppose they had repeated the task 200 times. Even then a "desirable prize" at the end would not, perhaps, say on the 100th trial, be much more incentive to work their very best than would a promise of heaven at 80, be an incentive to a boy of 10, to be good.

In a study of Rivalry the performer, in spite of himself, tended to vary with his rival.<sup>5</sup>

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<sup>5</sup> School and Society. To appear shortly.—Hazel Coburn, Helen Collins and Garry C. Myers.

Morgan's<sup>6</sup> study of lifting unseen weights well shows that what a subject does is not a certain measure of what he can do. Adaptation to drudgery, attitude, susceptibility to motivation and willingness to keep at the job, naturally would become more effective factors after many trials than in the early stages of the race. Perhaps the later trials measure these factors rather than mere capacity to do the work.

The fact that those subjects who knew their own and one another's rate of progress shifted relative rankings in the group far more than those to whom all rates were unknown, suggests factors at work other than mere capacity for the task. Indeed it is pretty safe to assume that all other things being equal the performer works the hardest at or near the outset of a task.

Had Hollingworth correlated the first or fifth trial with each of the others he would have found a descending instead of an ascending correlation. A much better case he might have made, too, could he have shown that on the 130th trial the subject's ranking in the tests correlated more closely with their intelligence than did their 1st or 5th trial. The writer computed such correlations for card sorting in class 16.

#### CORRELATION OF INTELLIGENCE WITH

Initial performance.....	— .14
Median first 5.....	+ .13
Median fourth 5 (End 1st day).....	— .29
Median eighth 5 (End 2nd day).....	+ .07
Median twelfth 5 (End 3rd day).....	+ .18
Median fourteenth 5 (Final five).....	+ .07

These correlations, all of which practically fall within the P.E., reveal no definite change with practice.

What then is the *relation of card sorting to intelligence*?

The initial average record per 25 seconds for the group 16 which is a marked ability class selected from among about 100 students, is 22.8 cards; average of the 1st 5, 26.9. For class 10 (a regular class) the corresponding figures are 21.8 cards and 27 cards. The initial performance of the 8 ranked highest for general intelligence (class 16) was 20.7 cards, of 8 ranked lowest 28.1 cards.

From these data and from the above correlations there seems to be no relation between general intelligence and card sorting ability.

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<sup>6</sup> The Overcoming of Distraction and Other Resistances. Archives of Psychol., No. 35, Science Press.



*What is the relation of highest gain in card sorting to general intelligence?*

The greatest gain by class 16 was 105 per cent.; by class 10, only 94 per cent. (The highest record appeared from the fourteenth trial upwards.) The gain of the last or 70th performance over the first was for class 16 (of marked ability), 76 per cent.; class 10, 61 per cent. The 8 best in general intelligence gained 129 per cent.; the 8 poorest, 81 per cent. On the last trial, the gain per cent. by the 8 best and 8 worst was, respectively, 94 and 58. The gain of the average of the last five trials over the average for the first five is, for class 16, 30 per cent.; for class 10, 20 per cent. The greatest gain and the gain on the last trial correlated with intelligence,  $+.48$  (P.E. .129) and  $+.34$  (P.E. .149), respectively. Between the highest gain for the 70 trials and the highest gain for the first 20 trials there was a correlation of  $+.66$  (P.E. .095). Doubtless, then, a very certain test of intelligence is the capacity to gain. Whereas with the actual performance there was no relation to intelligence, but at the same time a good positive correlation with gain in performance, a problem of good promise would be to determine how much the relative correlation with gain would be changed if the performance per se were a strong measure of intelligence.

Colvin<sup>7</sup> found a similar measure of intelligence.

Five normal children were paired with 5 subnormal children of the same mental age and given the Cancellation (a) test. "A comparison of the learning curves showed that in every case the normal child made greater improvement with less fluctuation than did the subnormal child."

Later Strong found that whereas 4th grade normal children in 14 days' drill of 2 minutes, advanced from 38 simple addition combinations to 66 such combinations, a class of defective children of the same age but still in the 2nd grade advanced only from 7 to 14 such problems. He concludes that the shape of the curve base on simple arithmetic performance correlates considerably with general intelligence.<sup>8</sup>

*Does the performer who attains the highest maximum tend to gain most?*

Class 16 were ranked on the basis of their maximum single performance regardless of the trial in which this performance occurred and in like manner on the basis of the greatest total

<sup>7</sup> Notes on Certain Aspects of Learning. As determined by the Binet Tests. *Psychol. Bull.*, 12, 1915: 67-68.

<sup>8</sup> The Learning Curve as a Diagnostic Measure of Intelligence. *Psychol. Bulletin*, 1917, 14: 153-154.

gain per cent. These two rankings correlated  $+.57$ . The average gain for the 3 performers who attained the highest maximum records was 50 per cent.; for the 3 who attained the lowest maximum only 21 per cent. The question, then, is answered affirmatively.

*Does the performer who reaches the highest point tend to end best?*

The ranking of the maximum performances with that of the 14th or last five-group correlates  $+.64$ . Again there is an affirmative reply.

*Does the performer who reaches the highest point tend to start best?*

The correlation between the rankings in question here is  $+.43$ . It would seem, therefore, that the final performance is a better measure of the maximum performance (last five) than is the initial (first five) performance. The difference, however, is negligible in the light of the exceptional mode of performance by X noted above. The correlation for the other 15 performers is  $+.79$ .

*Do individuals of a group become more or less alike with practice upon the same work?*

Here all 27 subjects were studied. The M. V. of the several subjects from the average, for each succeeding performance was obtained. Then the median of each succeeding group of 5 M. V.'s divided by the median of the averages for these respective groups was considered the measure of variability among the performers. These 14 succeeding ratios are: .11, .13, .12, .14, .11, .14, .11, .12, .13, .16, .14, .14, .13, .14. Likewise the variability for cube fitting, among the several individuals for the 23 successive single trials divided by the average was as follows:

RATIO OF M. V. (FROM AVERAGE FOR EACH SUCCESSIVE PERFORMANCE)  
TO AVERAGE PERFORMANCE FOR EACH TRIAL

Trial.....	1	2	3	4	5	6	7	8	9	10
When subjects knew.....	.08	.13	.14	.13	.13	.11	.10	.08	.10	.12
When subjects did not know	.12	.13	.12	.12	.10	.07	.11	.12	.13	.10
Trial.....	11	12	13	14	15	16	17	18	19	20
When subjects knew.....	.21	.09	.12	.10	.11	.07	.12	.11	.09	.11
When subjects did not know	.15	.09	.09	.09	.09	.11	.09	.09	.11	.11
Trial.....	21	22	23	24	25	26	27	28	29	30
When subjects knew.....	.07	.09	.08	.09	.15	.13	.12	.12	.12	.12
When subjects did not know	.12	.09	.10	.15	.12	.12	.12	.12	.12	.12

Thorndike<sup>9</sup> in like manner found about the same ratio of M. V./Ave. at the beginning and end of practice in mental multiplication of one three place number by another.

From these data one cannot say whether practice makes individuals more or less alike.

*Does an individual become more or less consistent with practice?*

The group of ten were studied on this point. Each individual's records were studied in series of 5 records. The variability was computed from the median of each successive 5 trials and the M. V. was derived; this divided by that median was the chosen measure of variability. The averages of these ratios by the class for the successive 14 fives are: .085, .044, .048, .049, .047, .052, .037, .055, .051, .033, .041, .050, .049, .053. Although there is a drop from the first five to the second five, thenceforward there is no appreciable loss or gain in individual variability. Therefore it seems that whereas the individual becomes a little more regular in performance after a few trials this regularity is not improved by further practice. Furthermore, influence on variability by the length of intervals between test days is not at all revealed by these data.

In this respect Woodworth (Mimeographed Notes, p. 19) points out that while, to ordinary observation, practice makes an individual more regular Ruger's data on puzzle solving suggest uncertainty on this subject. On the other hand Hollingworth speaks of decreased individual variability with practice for his subjects. (Vocational Psychology, p. 251.) Certainly more data on this point are desirable.

For the 10-group the ranking for the greatest gain per cent. correlated with the ranking in smallness of variability gives —.28, P.E. .20. Apparently then there is no relation between regularity of the performer and his degree of progress, as applied to card-sorting.

### CONCLUSIONS

1. The relative ranking of individuals of a group working at the same task over a long period of time, tends to remain pretty generally the same. The first five performances are as good measure of the remaining 13 five trials as are the last five trials of all others. After a few trials there is no certainty that any performance more definitely measures capacity than any other. Native capacity is pretty strongly evidenced.

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<sup>9</sup>*Amer. Jour. Psychol.* 1908, 19: 374.

2. There is practically no correlation between card sorting and intelligence, at any stage in the series of practices.
3. The correlation of the highest gain in card sorting, with intelligence, is  $+.48$ .
4. There is a positive correlation
  - a. Between maximum performance and maximum gain ( $+.57$ ).
  - b. Between maximum performance and final performance ( $+.64$ ).
  - c. Between maximum performance and initial performance ( $+.43$ ).
5. Practice does not make the individuals more or less alike.
6. Practice after the first few trials does not make the individual a less regular performer.
7. No correlation obtained between regularity and gain in performance.
8. Doubtless one or a few trials in the average mental test is about as good as an infinite number of trials.